QWEBREPORT, THE ULTIMATE TOOL FOR ONLINE POWER QUALITY MONITORING

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ABSTRACT

Power Quality Monitoring in the different points of the grid and at utility's customers sites produces a large amount of data that has to be presented in an easy way to different types of users. This paper describes how it is possible to provide this information in a very simple and fast way through the web, using compressed indices and supporting different user types.

NOMENCLATURE

Power Quality RTU: Remote Transmitter Unit, a Power Quality measurement instrument, for fixed installation, with remote communication capabilities.
GPRS: General Packet Radio Service, a standard for wireless data communication.
AMR: Automatic Meter Reading, a software to read automatically remote revenue meters
PQDIF: Power Quality Data Interchange Format, described in Standard IEEE P1159.3

INTRODUCTION

ENERGY market has been submitted to recent drastic modifications: market changes with the deregulation, technological changes both production and distribution (distributed generation, micro grids, etc.) and in the loads (power electronics, microcontrollers, etc). Access to power quality data is becoming extremely important in this situation.

Nevertheless the large amount of data, the different ways it has to be presented for different users, the need for a common representation to enable multi-site, multi-period overview analysis and an easy access from different users poses some difficulties.

In this paper we will briefly describe how it is possible to provide through the web such type of information, to meet the following main requirements:

1. Provide information for non-technical users, like utility customers, to help them reducing the impact of power quality problems in their production.
2. Provide Power Quality standard compliance reports for regulators
3. Provide information for the utilities planning departments

We will apply what has been discussed in [1] and [2].

THE DIFFERENTE DATA LEVELS

Two different types of data will be considered in this paper:

1. continuous disturbances, which will be evident through long term recordings
2. discrete disturbances like voltage dips, swells and interruptions, which will result in event list recordings.

For the purpose described above we will consider out of the scope of this system, oscilloscope or transient triggered recordings, like those obtained by Digital Fault Recorders.

At the lower level data is obtained from Power Quality RTU's, which should be build according to IEC 61000-4-30 standard [3]. These provide a site pre-treatment both for continuous data (calculated in the base of 10/12 cycles) and event data (calculated in the base of 1 cycle window shifted each ½ cycle).

The pre-treatment for the continuous data will result in a 10 second aggregation file for the system frequency and 10 minute aggregation files for rms voltages, THD, the first 40 harmonics, flicker and unbalance. A flagging principle is necessary to mark as invalid frequency, flicker, harmonics, THD and unbalance during a voltage sag or interruption.

The pre-treatment for the event recordings will result in an event list with the start time, retained voltage, duration and phase/s affected. The event threshold to begin detection can be defined as a percentage of the nominal voltage ("declared input voltage" in IEC 61000-4-30) or as a percentage of the pre-event voltage ("sliding voltage reference" in IEC 61000-4-30). A hysteresis will be used in the determination of the event end. Retained voltage should be indicated as a percentage of nominal voltage.

To assure data integrity, the Power Quality RTU's should keep in memory at least the data for one week.

For Power Quality RTU's located in Sub Stations, communication should be preferably made through Ethernet/WAN connection. For devices installed in Transformer Stations or at Customer's sites, communication should be wireless, preferably GPRS, for low communication costs, calculated on data exchanged and not on the connection time. Technologies using data pushing mechanisms through Internet will normally result in lower communication costs.

The second data level corresponds to one or more relational databases that will keep the long term and the event recordings obtained from the different Power Quality RTU's. Probably different databases will be necessary to support devices from different manufacturers; unless a multi-vendor system will be used, similar to an AMR system, with support for Power Quality data. The use of a standard format, like PQDIF (IEEE P1159.3) [4], to import data from different devices, is highly recommended.
The third data level corresponds to the post-processing like percentile statistical calculation for the continuous Power Quality indices, the time and phase aggregation for the events and resulting event Power Quality indices.
At this level user authentication takes also place to define which sites and which user profile will be available for each individual user as well as the user profile definition (right access to administration, configuration, reports and graphs), administration and configuration.
Administration and configuration is made, as all the remaining data accesses, through the Web.
By administration we understand the definition of user profiles, site access and user accounts.

By configuration we understand the definition for:

A. event aggregation (fig. 1)

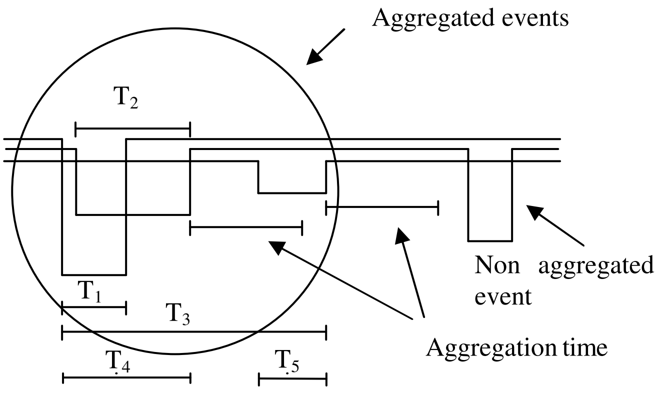

Fig. 1. Time and phase event aggregation

a) aggregation method (rule defining if swells following a sag/interruption are aggregated or not in the same event or if sags/interruptions following a swell are aggregated in the same event),
b) event qualification (duration and retained voltage limits to accept events to be aggregated),
c) aggregation time (default 60 sec.)
d) resulting duration (see Fig.1): total duration – T_3; duration of the deepest event – T_1; duration of the longest event – T_2; sum of the durations – T_4+T_5; equivalent duration – T_{eq} as defined in the following expression, where ΔU_i is the voltage amplitude for event *i*, ΔU_{max} is the amplitude of the deepest event, and ΔT_i is the duration of event *i*

$$\Delta T_{eq} = \frac{\sum_{i=1}^{n} \Delta U_i \times \Delta T_i}{\Delta U_{\max}} \quad (1)$$

e) resulting retained voltage (retained voltage of the longest event or of the deepest event)

B. Standard limits for the continuous recordings:

a) minimum and maximum limits for the voltage and frequency,
b) limits for the 5% and 95% cumulative values for the voltage
c) limits for the 5% and 95% or 0,5% and 99,5% cumulative values for the frequency,
d) limits for the 95% cumulative values for short and long term flicker, unbalance, THD and the individual harmonics.
The fourth and last data level comprises the data presentation, through the Web, for which a complete standard browser should be used without the need to install any additional software, as plug-ins, in the user PC.

THE DIFFERENTE USER TYPES

Different users have different needs and different technical background. We can differentiate four main user types:
1.Utility's customers do not have normally a high electro technical knowledge. What is normally required is a time tagged event list, an event qualification through an ITIC graph or a classification table enabling the correlation with production problems, a min/max voltage time graph (based on the 10/12 cycle rms calculation) and THD information over the selected period.
2.Internal users from the utilities, as well as external users from Universities/Schools should have access to min/max 1%, 5%, 95% and 99% cumulative values as well as time diagrams for permanent recordings. As an overview, site Power Quality indices for each continuous parameter must be presented. The individual and aggregated event lists, as well as event qualification through an ITIC graph are necessary. Single parameter power quality indices should be used to provide overview information
3.Regulatory users must have access to multi-site and multi period compliance overview, as well as detailed multi-site and multi-period compliance reports. Single site power quality indices should be used to provide overview information
4.Administration users must access administration and configuration panels.

THE POWER QUALITY INDICES

For a fast overview of the data, especially when comparing different sites and different periods, a single Power Quality index is highly recommended.
Nevertheless we think that too much information will be lost if a step is made to a single index trying to accommodate both discrete and continuous disturbances.
We will consider two types of indices, one for continuous disturbances and another for discrete disturbances.

A. Index for Power Quality continuous disturbances

For continuous disturbances we will consider the limits of a standard like EN 50160 [5] or the limits of an increased quality contract for each one of the measured parameters:

- Rms voltage
- Frequency
- Unbalance
- Short term and long term flicker
- THD
- Harmonics from 2nd to 25rd (or up to the 40th)

A normalization process will take place, as referred in [1] and [2], dividing each percentile by the corresponding limit. In normalized form, an index is at the limit of acceptability when its value is one. In the case of rms voltages and frequency, that have maximum and minimum limits, only the greatest value will be retained:

$$PQI_{RMS} = \left|(U_{NOM} - RMS_{0.05})/(U_{NOM} - Limit_{0.05})\right| \quad (2a)$$

or

$$PQI_{RMS} = \left|(RMS_{0.95} - U_{NOM})/(Limit_{0.95} - U_{NOM})\right| \quad (2b)$$

Fig.2 represents an overview graph after this normalization process of what can be called single parameters power quality indices. The percentage of valid data for the chosen period is also presented.

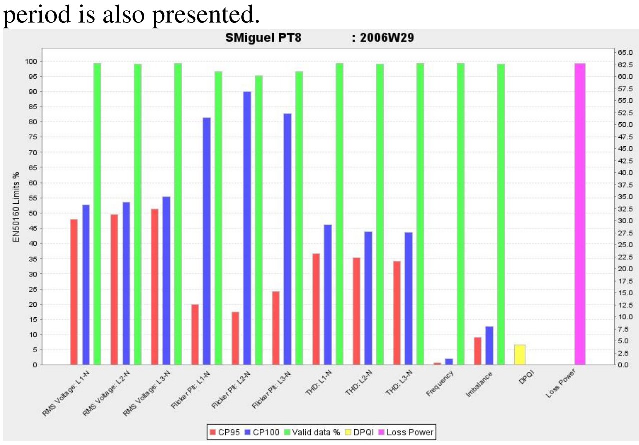

Fig. 2. Power Quality overview in one site

While this representation offers a good overview about the continuous disturbances in one site , it is not practical for a fast multi-site and multi-period analysis. For such an analysis a single site power quality index is required.
To compress even more the information to a single index we will retain only the greatest value from the three phases. As proposed in [2], if all the resulting values are less than one, the greatest value will then be used to represent the site single Power Quality index for continuous disturbances. If one or more resulting values are greater than one, then the site single Power Quality index for continuous disturbances will be the sum of all resulting values greater than one.

B. Index for Power Quality discrete disturbances

Several indices have been proposed to simplify the magnitude-duration characterization representing discrete disturbances [6].
Some of those indices are based in the loss of voltage:

$$L_E = \int \left\{1 - V(t)^2\right\} dt \qquad (3)$$

Others are based in loss of energy. The energy lost during a voltage sag event is a function of the missing voltage and the time duration of the sag event:

$$L_E = \int \left\{1 - V(t)^2\right\} dt \qquad (4)$$

Heydt and Thallam [7] proposed a method to measure lost energy in a sag event, referred to the CBEMA curve (to include non-rectangular events an integral expression should be used) :

$$W = \left\{1 - \frac{V}{V_{nom}}\right\}^{3.14} \times T \qquad (5)$$

And for a three phase event:

$$W = \sum_{i=1}^{3} \left\{1 - \frac{V_i}{V_{nom}}\right\}^{3.14} \times T_i \qquad (6)$$

M. Fleming [8] proposed a severity index relative to a reference curve, like CBEMA or ITIC:

$$S_e = \left|\frac{V - 100\%}{V_{REF}(t) - 100\%}\right| x100\% \qquad (7)$$

During the aggregation process we will calculate W from (6) for each aggregated event. For the period selected (one week, for example) the different W_i will be summed to result in a single site index.
The effect on customer's equipment is said to be normally better represented by an index based on energy, but this tends to be strongly biased by long interruptions. Mainly for industrial customers, like food, glass, etc. the number of dips and interruptions, more that the total interruption time, is much more severe. Severe dips and interruptions will require a complete re-start of the operations (for example: sterilization, discharging and re-heating, re-start a complete

new piece from scratch, etc.), regardless of the event duration.
To produce a single site severity index we will calculate (7) from the aggregated event list, for events outside ITIC limits, multiplied by the number of affected phases. For the period selected (one week, for example) the different severity indexes will be summed to result in a single site index. Energy Loss (6) can also be represented.
Fig. 3 represents the two indices for different sites obtained from real measurement data.

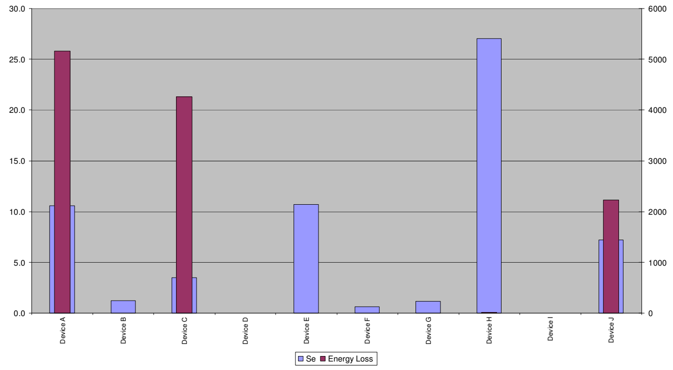

Fig. 3. Comparison between single discrete disturbance indices (W_i are the thinner bars)

It is evident in this case the difference between the two indices. Industry connected to network measured by device H (highest thicker bar) suffered much more losses than industry connected to network measured by device A. Energy Loss is an important index for a domestic or simple tertiary user that are not affected by swells, but for an industrial user the severity index (7) will normally provide a more accurate relation with the production losses.

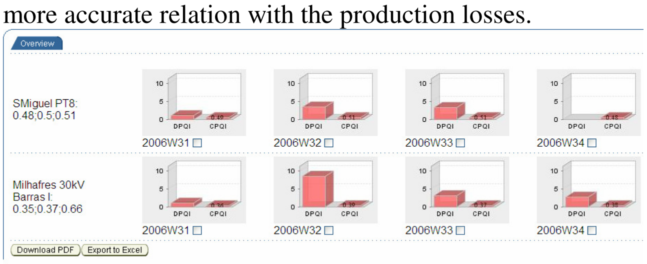

Fig. 4. Single Quality indices for a multi-site, multi-period representation

We will use the severity index Se (7) for the multi-site, multi-period overview, together with the continuous power quality index, as shown in Fig. 4, in a simulation for two sites, for a period of 52 weeks. For normalization purposes the severity index Se (7) for events can be represented as an average per week or per month, for easier reading in a single scale graph.
In the aggregated event list for one or multiple sites both energy loss (6) and severity (7) indices will be presented.

CONCLUSION

In this paper we described a web based power quality information system to provide relevant information for different types of users.

We specified the basic needs in terms of the Power Quality RTU's to be used, channels to support the remote communication, and the functions at each data levels.

Different types of users require different types of treated information, filtered by a user profile definition.

To support an easy overview we discussed the need to present data through single power quality indices, together with a short discussion that justified our selection.

The software QWebReport supports the above mentioned technologies and needs as a Power Quality Information web tool.

The QWebReport emerge like the ultimate tool for online power quality monitoring providing a constant interaction whit the user.

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